Midterm Quiz: Modern Physics 201
March 14, 2014

Formula sheet provided. Total 40 points. Individual values follow each question. Usual conventions for frames S and S' apply.

1. A pion is at rest in frame S'. Relative to the S frame it is moving at $0.8c$ in the positive x-direction. The pion is created at $t = t' = 0$. Following our usual convention this is also when the origins of the frames coincide.

   (a) Give β and γ. (2)

   (b) A pion at rest has a lifetime of 2.6×10^{-8} s. How much time elapses in the frames S' and S between creation and decay? Is one of them a proper time? Which one? (3)

   (c) Convert these times to metres. (1)

   (d) Give the x and x' of the decay event using information you have calculated or been given in the question and in 1b. Show that they satisfy both the forward and inverse Lorentz transforms for x and x'. (3)

   (e) Draw a space-time diagram that includes the light cone, roughly correct scaling for the x' and ct' axes, and a worldline for the pion. (There is graph paper for this.) I suggest an x scale of -5 to 15 m and a ct scale of -5 to 15 m. (5)

   (f) Highlight how your answers in 1c and 1d can be found on the space-time diagram. (3)

   (g) Calculate the space-time interval using your method of choice. Do you expect it to be space-like or time-like? (2)

2. (a) A proton has a rest mass of 938 MeV/c^2 and a relativistic energy of $E = 1400$ MeV. It is moving in the *negative* x-direction. Calculate p_x and u_x. You may use any method you want and any appropriate units. (4)

   (b) Now consider a frame S' with $\beta = 0.7$. If an object has $u_x = -0.74\,c$ calculate u'_x. (3)

   (c) E'=2930 MeV and p_x=-2775 MeV/c. Numerically show that the rest mass is invariant. (2)

3. (a) What were Michelson and Morley trying to discover with their experiment? Comment on the validity of the Galilean velocity transforms in this context. (3)

   (b) Give the position 4-vector. What is the matching 4-scalar? (3)

   (c) What is the key to resolving the barn-pole paradox i.e. the farmer claims the "short" moving pole fits in the barn but the son claims there is no way pole can fit in the "shorter" barn? I just want one phrase but use a quick space-time diagram if you like (i.e. don't worry about scaling) (3)

   (d) What is the equivalence principle of general relativity? Use it to explain why objects in an upward accelerating elevator appear heavier. (3)